# SIMULATION AND PERFORMANCE OF MULTIPLE INPUT MULTIPLE OUTPUT ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING WIRELESS LOCAL AREA NETWORK 802.11a

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To my beloved Mother, Brother, Sisters and Wife.

Thank you for all your motivation and advise.

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# ABSTRACT

802.11a and Hiperlan/2 are two major WLAN standard developed by the ETSI and IEEE respectively to meet demands for a mobile with high bandwidth data, voice and video access. This research studies the IEEE 802.11a standard has it is predicated by the telecommunication industry, to be next leading, advance and important WLAN technology. This system is expected to provide channel adaptive data rates up to 54 Mb/s in a 20 MHz channel spacing in the 5 GHz radio band. An overview and description of IEEE 802.11a is presented. Literature review on past white papers and journal research data is referred before modelling the IEEE 802.11a physical layer. Using Simulink in conjunction with the Matlab software the simulated physical layer and BER versus Eb/No performance results is presented for each defined transmission mode 1 to mode 8 by the IEEE 802.11a standard. The simulated physical layer consists of a transmitter and receiver under a real WLAN mobile link channel. This mobile link channel consists of AWGN, Path Loss, Rician and Rayleigh Fading. Computer simulations with different delay spread values are carried out and the achievable performance with BER floor value of $10^{-5}$ in a multipath environment is shown. In which the results show that with the increase of delay spread value there is a graceful degradation of achievable performance. This may be applied to mitigate multipath effect using OFDM based transmission. Further performance improvement is done by modelling a MIMO extension for the existing design. The MIMO design consists of a 2 transmit antenna and 2 receive antenna extended to OFDM design. Results have shown that an average of 8% improvement of Eb/No at BER floor value of $10^{-5}$ for all modes with common modulation format and code rate. The research will be applicable in studying and comparing WLAN systems that do not deploy OFDM or MIMO-OFDM in terms of achievable performance.

# ABSTRAK

802.11a dan Hiperlan/2 telah direka oleh IEEE dan ETSI untuk memenuhi permintaan tersebut. Kajian ini dijalankan untuk mempelajari IEEE 802.11a kerana ia diramalkan menjadi teknologi canggih dan terkini dipasaran komunikasi tempatan. Standard ini akan membekalkan kapasiti 54 Mb/s dalam jalur lebar 20 MHz di jalur radio 5 GHz. Kajian literatur dijalankan terlebih dulu sebelum mereka lapisan fizikal IEEE 802.11a. Dengan menggunakan Simulink dan Matlab lapisan fizikal ini disimulasikan untuk menghasil graph prestasi BER lawan Eb/No untuk setiap mode 1 hingga mode 8. Lapisan ini terdiri daripada pemancar, penerima dan saluran. Saluran ini terdiri daripada komposisi 'AWGN', 'Path Loss', 'Rician' dan 'Rayleigh'. Simulasi komputer dengan pelbagai nilai 'delay spread' telah dilaksanakan. Graph prestasi BER lawan Eb/No dengan nilai terendah BER sebanyak $10^{-5}$ telah dihasilkan. Keputusan menunjukan penambahan nilai 'delay spread' akan mengurangkan prestasi secara sedikit demi sedikit. Untuk mengkaji penambahan prestasi, kajian ini telah mereka sistem MIMO sebagai penambahan diatas sistem OFDM. Sistem ini mengandungi dua sistem pemancar diikuti dengan dua sistem penerima. Hasil kajian menunjukan terdapat secara purata sebanyak 8 % penambahan prestasi untuk semua sistem modulasi dan kadar kod. Kajian ini boleh digunakan untuk mempelajari dan membezakan sistem komunikasi wayarless yang mempunyai sistem OFDM sahaja atau MIMO-OFDM dari segi pencapaian prestasi.

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| | | |
|---|---|---|
| AM | - | Amplitude Modulation |
| ACK | - | Acknowledgement |
| ASIC | - | Application Specific Integrated Circuit |
| A/D | - | Analog To Digital |
| AWGN | - | Additive White Gaussian Noise |
| AP | - | Access Point |
| BER | - | Bit Error Rate |
| BRAN | - | Broadband Radio Access Networks |
| BPSK | - | Binary Phase Shift Keying |
| CAC | - | Channel Access Control |
| CTS | - | Clear To Send |
| CSMA/CA | - | Carrier Sense Multiple Access/Collision Avoidance |
| CIR | - | Carrier-to-Interference Radio |
| CDMA | - | Code Division Multiple Access |
| CNR | - | Carrier Noise Ratio |
| DAB | - | Digital Audio Broadcasting |
| DVB | - | Digital Video Broadcasting |
| DSSS | - | Direct Sequence Spread Spectrum |
| DSP | - | Digital Signal Processing |
| D/A | - | Digital To Analog |
| DMT | - | Discrete Multi-Tone |
| ETSI | - | European Telecommunications Standards Institute |
| EIRP | - | Effective Isotropic Radiated Power |
| FCC | - | Federal Communications Commission |

| | | |
|---|---|---|
| FM | - | Frequency Modulation |
| FHSS | - | Frequency Hopping Spread Spectrum |
| FEC | - | Forward Error Correction |
| FFT | - | Fast Fourier Transform |
| GSM | - | Group Special Mobile |
| GO | - | Geo Optics |
| GUI | - | Graphical User Interface |
| Hz | - | Hertz |
| HPA | - | High Power Amplifier |
| IEEE | - | Institute of Electrical and Electronic Engineers |
| IP | - | Internet Protocol |
| ISM | - | Industrial, Scientific, Medical |
| IFFT | - | Inverse Fast Fourier Transform |
| IF | - | Intermediate Frequency |
| ITS | - | Institute for Telecommunication Sciences |
| ISI | - | Inter-Symbol Interference |
| ISO | - | International Standards Organization |
| LOS | - | Line Of Sight |
| LLC | - | Logical Link Control |
| LAN | - | Local Area Network |
| NLOS | - | Non Line Of Sight |
| NIC | - | Network Interface Card |
| Mbps | - | Mega bits per second |
| MAC | - | Media Access Control |
| MIB | - | Management Information Base |
| MCM | - | Multicarrier Modulation |
| MT | - | Mobile Terminal |
| MFN | - | Multi Frequency Networks |
| OSI | - | Open System Interconnect |
| OFDM | - | Orthogonal Frequency Division Multiplexing |
| PC | - | Personal Computer |

| | | |
|---|---|---|
| PCF | - | Point Coordination Function |
| PDA | - | Personal Digital Assistants |
| PDU | - | Protocol Data Unit |
| PSDU | - | Protocol Service Data Unit |
| PAN | - | Personal Area Networks |
| PER | - | Packet Error Rate |
| PSK | - | Phase Shift Keying |
| PSD | - | Power Spectral Density |
| QPSK | - | Quantary Phase Shift Keying |
| QAM | - | Quantary Amplitude Modulation |
| RF | - | Radio Frequency |
| RTS | - | Request To Send |
| SOHO | - | Small Office Home Office |
| SNR | - | Signal Noise Rate |
| SDR | - | Software Defined Radio |
| SFN | - | Single Frequency Network |
| TDD | - | Time Division Duplexing |
| TDMA | - | Time Division Multiple Access |
| TCP | - | Transport Control Protocol |
| TWT | - | Traveling Wave Tube |
| UHF | - | Ultra High Frequency |
| UMT | - | Universal Mobile Telecom |
| U-NII | - | Unlicensed National Information Infrastructure |
| VLSI | - | Very Large Scale Integration |
| WLAN | - | Wireless Local Area Network |
| WECA | - | Wireless Ethernet Compatibility Alliance |
| WHT | - | Walsh-Hadamard Transform |
| WAN | - | Wide Area Network |
| 1G | - | First Generation |
| 2G | - | Second Generation |
| 3G | - | Third Generation |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Wireless Local Area Network

Wireless Local Area Network (WLAN) is known to be an extension of wired area networks. Wired local area network and WLAN share the same basic principle in operation. The only difference is by means of delivering data to a certain terminal or point. WLAN uses Radio Frequency (RF) to transmit and receive data over the air. Minimizing the need to be wired connected [1]. WLAN enables power of freedom so users are able to access a certain information with ease and seamlessly.

Wireless LAN industry has emerged as one of the fastest growing segments of the communications industry and promises a lot of potential growth. Cahners-Instat foresees the industry growing from 1.1 Billion USD of 2000 to 5.2 Billion USD by 2005, economic growth beyond that will be very significant [1].WLAN offers productivity, convenience and cost advantages over wired networks. The advantages WLAN offer are [2]:

a. Mobility – users are able to access information at anywhere and at any time.
b. Installation speed and simplicity – WLAN are easy and fast to be installed.
c. Installation reliability – network can be installed where wired network are impossible to be installed.

d. Reduced Cost of Ownerships – higher initial investments but long-term cost benefits are greatest in dynamic environments requiring frequent moves and changes.

e. Scalability – can be configured in a variety of topologies to meet the needs of specific applications and installations.

Figure 1.1 illustrates the two way connection between the Ethernet hub with access points and server. The two way arrow represents wired connection between devices. Laptops are connected to the system via wireless connection. WLAN have two kind of network configuration that is an ad-hoc and client to access point network. Client to access point network is more rigid and requires the laptops to be always connected and synchronized with an access point [2].

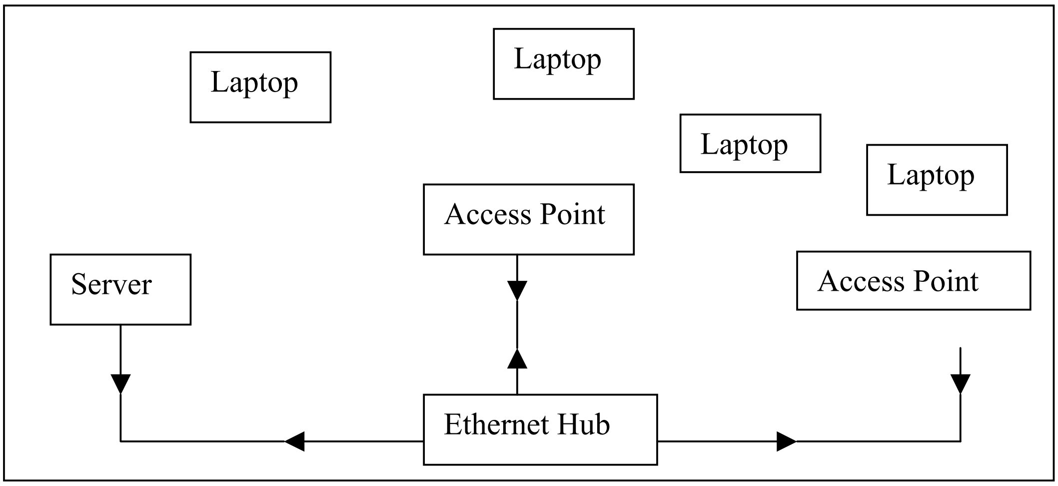


**Figure 1.1** Ad-hoc and client to access point network [2]

WLAN data is a multimedia data. Multimedia data computing is time bounded and require high data rate. A 54 Mbps WLAN will have a 70% of nominal data rate equal to 38 Mbps [3]. Achieving this data rate requires network protocol to be efficient and robust. Seventy percent data rate is rule of thumb for true data rate estimation in WLAN.

With the complexity of WLAN is, people have yet to become accustomed to wireless has there are a variety of issues to deal with other then just swapping wires. It involves dealing with interference, ensuring that all areas are covered, tracking a mobile user's whereabouts and managing battery power, and other things [4]. Implementation of WLAN has one physical layer per network must be able to support, movable and mobile stations moving at pedestrian and vehicular local premises environment speeds.

WLAN standards are expected to kick start wireless industry by making it feasible to invest in infrastructure and developing low cost hardware for implementation. Rapid growth is likely as the price of the technology drops, standards are adopted and people become accustomed to wireless solution. Standards will assure user interoperability by designing one WLAN Media Access Controller (MAC) that can support various physical layers [3]. Various physical layers give a user to have maximum flexibility. A system designer usually chooses a physical layer based on a particular installation and environment.

## 1.2 WLAN Standards

WLAN transmit using radio frequencies, which are regulated by the same type of laws used to govern such things such has as AM/FM radios. The Federal Communications Commission (FCC) in the United States regulates the use of wireless LAN devices. Radio bandwidth approved for WLAN communications falls in 900 MHz, 2.4 GHz, 5.16 GHz and 5.7 GHz band [3].

European Telecommunications Standards Institute (ETSI), introduced regulations for 2.4GHz in 1994. Hiperlan is a family of standards in the 5.15-5.2 GHz and 19.3 GHz frequency bands. Table 1.1 below illustrates the operating frequency WLAN frequency bands and typical data rates.

**Table 1.1 :** WLAN frequency bands and typical data rates [4]

| Wireless Technology | Data Rates |
|---|---|
| 400 MHz UHF | 4.8 – 19.2 Kbps |
| 900 MHz Spread Spectrum | 100 – 400 Kbps |
| 2.4 GHz Spread Spectrum | 1 - 2 Mbps |
| 2.4 GHz Future | More than 10 Mbps |
| 5.7 GHz Future | More than 20 Mbps |

Standards are created by groups of people that represent many different organizations such has academics, business, military and government [2]. The Institute of Electrical and Electronic Engineers (IEEE) have created and maintained several accepted operational standards and drafts.

Table 1.2 illustrates a brief comparison of capabilities of WLAN standards that is the main focus of the researchers in the world. A brief overview of standards is provided below:

**Table 1.2 :** Comparison of WLAN standards [2]

| Characteristic | IEEE 802.11b | IEEE 802.11a | HiperLAN2 |
|---|---|---|---|
| **Spectrum** | 2.4 GHz | 5 GHz | 5 GHz |
| **Maximum physical rate** | 11 Mbps | 64 Mbps | 54 Mbps |
| **Max data rate, layer 3** | 5 Mbps | 28 Mbps | 32 Mbps |
| **PHY** | DSSS (Direct Sequence Spread Spectrum) | OFDM | OFDM (Orthogonal Frequency Division Multiplexing) |
| **Medium access control** | CSMA/CA Carrier Sense Multiple Access/Collision Avoidance) | CSMA-CA | Central resource control/TDMA/TDD (Time Division Duplexing) |
| **Connectivity** | Connection-less | Connection-less | Connection-oriented |

| Characteristic | IEEE 802.11b | IEEE 802.11a | HiperLAN2 |
|---|---|---|---|
| **Frequency selection** | DSSS | Single carrier | Single carrier with Dynamic Frequency Selection |
| **Authentication** | No | No | NAI/IEEE address/X.509 |
| **Encryption** | 40-bit RC4 | 40-bit RC4 | DES, Triple-DES |
| **Handover support** | No | No | No |
| **Fixed network support** | Ethernet | Ethernet | Ethernet, IP, ATM, UMTS, FireWire (1394), PPP |
| **Management** | 802, 11 MIB | 802, 11 MIB | HiperLAN/2 MIB |
| **Radio link quality control** | No | No | Link adaptation |
| **Organization** | IEEE, WECA | IEEE, WECA | HiperLAN2 Global Forum (H2GF) |
| **OoS support** | PCF | PCF | ATM/802, 1p/RSVP/DiffServ (full control) |

a. IEEE 802.11 – the original wireless LAN standard that specifies the slowest data transfer rates (1-2 Mbit/s) in both RF and light based transmission.

b. 802.11b – describes somewhat faster data transfer rates (11 Mbit/s) and a more restrictive scope of transmission technologies. Promoted has Wi-Fi by the Wireless Ethernet Compatibility Alliance (WECA).

c. 802.11a – describes much faster data transfer data rate (54 Mbit/s) then 802.11b but lacks backwards compatibility with 802.11b.

d. 802.11g – describes data rates equally as fast as 802.11a and boasts the backward compatibility to 802.11b which requires making inexpensive upgrades.

e. HiperLAN/2 – developed by ETSI (European Telecommunications Standards Institute) to provide a broadband and most flexible connection between devices over the mobile channel.

### 1.2.1 Overview Of WLAN Standards

#### 1.2.1.1 The Open Air Standard

The Open Air Standard was established by Wireless LAN International Forum as an interoperable standard in the 2.4 GHz frequency band. Frequency Hopping Spread Spectrum technology is used to ensure high security and any immunity to interference. The standards specifies the physical and media access control layer requirement to achieve through data communications, roaming, security, configuration and coexistence [5].

#### 1.2.1.2 The ETS 300 328 Standard

The 2.4 GHz frequency band is used and utilized by other types of equipment such has the microwave oven. This creates interference and degrades performance. To mitigate this effect the ETS 300 328 standard suggests the use of Direct Sequence Spread Spectrum (DSSS) technique. This technique uses several frequencies to communicate by spreading over it. Eavesdrop is virtually impossible by just listening in.

The raw bit rate of equipment is normally 2 Mbit/s with a net throughput of typically range of 600 to 800 kbit/s. The effective radiated power from the antenna must not exceed 100 mW. This is significantly lower then allowed Federal Communication Commission (FCC) in United States. With that amount of power from the antenna, radio range is normally range of 20 to 50 meters indoor and range of 100 to 200 hundred meters outdoor [5].

#### 1.2.1.3 The HiperLAN Standard

HiperLAN is a European family of standards on digital high speed wireless LAN in the 5 GHz and 17 GHz frequency band [6]. The 5 GHz standard serves to ensure the possible inter operability of different manufacturers’s wireless communications equipment operating in this spectrum. It allows both synchronous and asynchronous traffic.

The HiperLAN standard only describes a common air interface including the physical layer for wireless communications equipment and leaving decisions on higher level protocol. It also defines Medium Access Control (MAC) sub layer and Channel Access Control (CAC) sub layer corresponding to the Data Link Layer (DLL) in OSI model.

MAC layer is responsible for handling multiple transmissions without intervention, performing time critical protocol functions to reduce overhead on processor and automatically performing simple frame exchange sequences without interrupting firmware [6].

There is no fixed infrastructure stated in HiperLAN standard. Two stations may exchange data directly, without any interaction from a wired or radio based infrastructure. If two HiperLAN stations are not in radio contact with each other, they may use a third station. The third station can relay messages between the two communicating stations. HiperLAN has relative high throughput and a raw bit rate of approximately 24 Mbit/s in MAC protocol [5]. Raw bit rate of 24 Mbit/s will be able to support multi-media communication.

#### 1.2.1.4 The NII/SUPERnet Standard

The National Information Infrastructure/Shared Unlicensed Personal Radio Network (NII/SUPERNet) enables wireless transmission of digital data and multimedia among computers and other information appliances, both within Local Area Networks (LAN) and between point-to-point site at rates of approximately 24 Mbps.

The NII/SUPERnet standard regulates the NII/SUPERnet devices under FCC. The goal of this new standard is to foster the development of a broad range of new devices and stimulate the growth of WLAN industries. It defines low power SUPERnet service of no more than –10 dBW across 200 m in the 5.15GHz - 5.35GHz frequency bands that will permit much faster wireless LANs to be designed for in-building use to meet a growing need [5].

### 1.2.1.5 The IEEE 802.11 Wireless Standard

The IEEE 802.11 specification is a wireless LAN standard developed by the Institute of Electrical and Electronic Engineering (IEEE) committee in order to specify an over the air interface between a wireless client and a base station or access point as well as among wireless clients [3].

There are two important layers stated by the standard. That is the Physical (PHY) layer and Media Access Control (MAC) layer. Physical layer defines modulation, signal characteristics, measuring the RF energy at the antenna and determining the received signal strength. The MAC associated with rules for accessing the wireless medium with the support of the physical layer. MAC is given the clear channel status for data transmission when PHY measures the RF energy below a specified threshold value in the antenna [3].

The MAC layer employs a collision avoidance protocol called CSMA/CA. In nature it is difficult to detect collisions signals in an RF transmission network and has a substitute collisions avoidance is employed. This protocol allows using Request To Send (RTS), Clear To Send (CTS) and data acknowledge (ACK) transmission frames to help prevent the disruptions caused by “hidden node” problem [7]. Figure 1.2 shows development stages of each WLAN standards from formation of standards until mass deployment of devices.

| | | |
|---|---|---|
| WIRELESS LAN STANDARD DEVELOPMENT | **INTEROPERABILITY** | Open Air |
| | **METRICS AGREED** | - |
| | **TEST LAB ESTABLISHED** | 802.11DS, 802.11FH |
| | **PUBLISHED STANDARD** | HiperLAN1 |
| | **STANDARD BODY FORMED** | 802.11HS, 802.11GHz, Home RF, Bluetooth |

**Figure 1.2** Current status and stages of each WLAN standards [3]

### 1.2.2 Importance Of Standards

In the 1990s WLAN devices has been mass deployed has predicted, and flat sales growth of wireless networking components prevailed. Propriety hardware was the only choice to install before 1998, but only for those application suitable for lower data rates and enough cost saving to warrant purchasing wireless connections. Today many organizations have propriety wireless networks for which high cost is need in order to maintain or replace hardware and software if an upgrade is required. Relatively low data rates, high prices and especially the lack of standards kept many end users away from purchasing WLAN [5].

WLAN is an enabling technology, proven over the last decade in vertical applications such as recording of retail transactions and management of inventory. Many hospitals and universities that now broadly use the technology with standard PC platforms have dramatically improved the services they provide to staff, patients, and students. These installations have increased productivity in the enterprise environment, and major corporations have turned WLAN.

The scalability is best demonstrated in the protection of historical building. In this buildings it is completely prohibited against any structural alterations such has drilling of holes for new cabling. WLAN is the only viable option for such an environment . WLAN can be quickly installed and placed into service. Organizations leasing office space may not want to invest in the installation and maintenance of wired LAN. Wireless LANs represent a one-time investment; once configured, wireless LANs can be moved from place to place with little or no modification, and will not incur additional installation cost [8].

Today WLAN are called has hotspots where casual surfers flock to public hotspots in airports, hotels, convention centers and coffee shops. Casual surfers with a WLAN card gain access to the Internet. WLAN networking setup allows laptop users to access the broadband connection from any room and desktop users to access the Internet without drilling holes for cables.

### 1.3 Research Background

The acceptances of wireless 2G technologies has been tremendous, even though systems with 2G are not interoperable. 3G technologies will some however will bring some convergence but is still a long way being a single global technology. 4G with Internet Protocol (IP) based is projected to fuse all sorts of networks and will bring convergence to all related technologies. In a dense user environment hot spots WLAN is said to be a complementary technology towards cellular technology [8].

Cellular mobile services operators offer WLAN services in major hot spots. Among the hot spots area are airport, hotels and coffee shops. This configuration is an ad-hoc network oriented. Their objectives to continuing offer higher throughput in a mobile environment, similar to performance user experiences in the SOHO (Small

Office Home Office) environment. WLAN is not a part of the evolution path of cellular network but as a wireless extension to SOHOs [8].

WLAN complements to the a wide area 3G network. It offers close inter-working to ensure proper delivery of services according to most appropriate available access network. Figure 1.3 illustrates WLAN has essential part of multi technology access network [9]. The future of all types of network will be IP based. IP will fuse all different network interface into one huge seamless network.

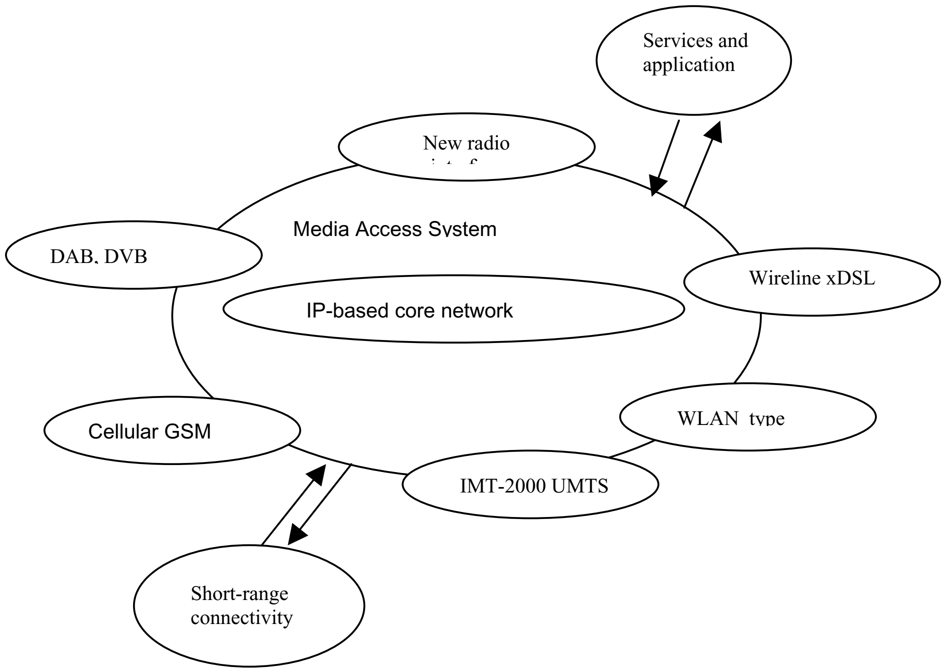


**Figure 1.3** A Multi Technology Network [9]

WLAN market seems to be evolving in a similar fashion to the networking industry as a whole, starting with the early adopters using whatever technology was available. The market has moved into a rapid growth stage, for which popular standards are providing the catalyst. The rate of growth is the big difference between the networking market as a whole and the wireless LAN market. WLAN offers so many flexibilities in terms of implementation.

As the WLAN technology improves, the cost of manufacturing and thus purchasing and implementing the hardware continues to fall, and the number of installed wireless LANs continues to increase. Standards that govern WLAN operation will increasingly stress interoperability and compatibility [9].

## 1.4 WLAN Problem Scenario

Indoor WLAN communication takes place between a single personal computer of notebook and the rest of LAN components. Traffic volume for an average user is generally low, for example if a device operating at a stated 11 Mb will have a true throughput of 1 to 2 Mb.When WLAN grows to serve a dozen links or even hundreds of links on an enterprise. Traffic volume for an average user degrades with number of users. A solution is needed to increase the traffic volume [3].

Hidden transmitter phenomenon generates multipath and localized packet retransmission. Hidden transmitter problem is something that is unavoidable. It occurs when a wireless node cannot hear one or more of the other nodes. Multiple nodes will attempt to transmit data over the shared medium simultaneously, causing more than one transmitting direct path between the transmitter and receiver. A multipath interference is created.

This effect is similar to a broadcast storm on a wired LAN segment and brings the traffic to a stand still. Interfering transmitters have a very detrimental effect on the performance of every wireless node in the network. This cause a 50 % performance of the entire network. There is a dire need for solutions that offer higher bandwidth and to decrease multipath problem [8].

Hidden node problem also results in retransmission of packet. This extra traffic consumes a small portion of the network bandwidth, but considered a part of the normal overhead associated with WLAN traffic. Active attempts are taken in order to reduce this overhead [8]. In general, researchers on Wlan intend to find a solution that will be able to meet the following criteria.

a. Need to increase higher bandwidth.

b. Need to decrease multipath problem.

c. Need higher rate of transmission.

d. Need to increase capacity/traffic volume.

## 1.5 Thesis Problem Statement

The purpose of this study is to investigate the characteristic of wireless local area network physical layers based on Orthogonal Frequency Division Multiplexing (OFDM) standards and achieving further improvements using OFDM Multiple Input Multiple Output (MIMO).

The physical layer defines the electrical, mechanical and procedural specifications for transmission of information over a communication channel and medium. WLAN physical layer is last layer in the Open System Interconnect (OSI) protocol stack of a common networking system defined by the International Standards Organization (ISO).

## 1.6 Research Objective

The research is to design and simulate the basic physical layer processing blocks of WLAN using Simulink and Matlab. The physical layers will be based on IEEE 802.11a Orthogonal Frequency Division Multiplexing (OFDM) standard. Higher Open

System Interconnect (OSI) layers of WLAN networking protocol stack will remain same.

Upon completion of the design, the research is to study and simulate the performance of the OFDM based WLAN. Further investigation is carried out to observe improvements using MIMO technique. Objectives of the research are:

a. To study IEEE 802.11a standard. This standard encompass the WLAN physical layer based on OFDM. Further studies are carried out on OFDM using MIMO.
b. To design the IEEE 802.11a standard WLAN physical layer initially with OFDM.
c. To simulate and produce error performance (BER versus Eb/No) of the design on various WLAN
d. To further investigate performance improvement with MIMO.

### 1.7 Thesis Outline

The thesis is organized into six chapters that completely covers this research. Chapter 1 covers the introduction of significant WLAN standards and its attributes. It defines the research problem statement and objectives. Chapter 2 provides explanation, principles and major concepts related to the research and simulation for WLAN systems. An explanation on the WLAN channel is provided.

Chapter 3 provides the explanation of the system level modeling and simulation setup of OFDM IEEE 802.11a using Matlab and Simulink. Here it explains how information is assimilated in the research and explains in details of the model itself with all of its composition and components. It is basically a transmitter and receiver with

WLAN channel in between. Chapter 4 provides the explanation for the extension of the OFDM model using MIMO to improve the performance.

Chapter 5 presents the results from the simulation of the model has explained in chapter 5. It provides a comparisons between produced results and theoretical results based on past research papers and journals and discussion on the results. Chapter 6 provides the conclusion and future work that can be undertaken to refine the research. The final chapter also provides an overall conclusion of the work conducted in this research project. Future works and recommendations are outlined.

## 1.8 Summary

The research objective are explained. A brief explanation of WLAN standards is provided with certain focus and interest in the IEEE 802.11a standard physical layers. Research background and thesis composition is explained. Following chapters outline the information has explained in the thesis outline. Chapter 2 explains the literature review, where the research quotes all the past work and research done related to the research.

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